Practitioner's Docket No.: 081468-0306625
Client Reference No.: P-0383.010-US

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

Confirmation No:

BEST et al.

Application No.: TO BE ASSIGNED

Group No.:

Filed: November 12, 2003

Examiner:

For: ALTERNATE SIDE LITHOGRAPHIC SUBSTRATE IMAGING

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

SUBMISSION OF PRIORITY DOCUMENT

Attached please find the certified copy of the foreign application from which priority is claimed for this case:

Country	Application Number	Filing Date
EUROPE	02257846.2	November 13, 2002

Date: November 12, 2003

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The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

02257846.2

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
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Anmeldung Nr:
Application no.: 02257846.2
Demande no:

Anmeldetag:
Date of filing: 13.11.02
Date de dépôt:

Anmelder/Applicant(s)/Demandeur(s):

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Device manufacturing method

In Anspruch genommene Priorität(en) / Priority(ies) claimed /Priorité(s) revendiquée(s)
Staat/Tag/Aktenzeichen/State/Date/File no./Pays/Date/Numéro de dépôt:

Internationale Patentklassifikation/International Patent Classification/
Classification internationale des brevets:

H01L/

Am Anmeldetag benannte Vertragstaaten/Contracting states designated at date of filing/Etats contractants désignées lors du dépôt:

AT BE BG CH CY CZ DE DK EE ES FI FR GB GR IE IT LI LU MC NL PT SE SK TR

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Device Manufacturing Method

The present invention relates to device manufacturing methods using lithographic projection apparatus comprising:

- a radiation system for supplying a projection beam of radiation;
- patterning means for patterning the projection beam according to a desired pattern;
- a substrate table for holding a substrate; and
- a projection system for imaging the patterned beam onto a target portion on a first side of the substrate.

The term "patterning means" should be broadly interpreted as referring to means that can be used to endow an incoming radiation beam with a patterned cross-section, corresponding to a pattern that is to be created in a target portion of the substrate; the term "light valve" has also been used in this context. Generally, the said pattern will correspond to a particular functional layer in a device being created in the target portion, such as an integrated circuit or other device (see below). Examples of such patterning means include: a mask table for holding a mask, a programmable mirror array and a programmable LCD array. For purposes of simplicity, the rest of this text may, at certain locations, specifically direct itself to examples involving a mask table and mask; however, the general principles discussed in such instances should be seen in the broader context of the patterning means as hereabove set forth.

For the sake of simplicity, the projection system may hereinafter be referred to as the "lens"; however, this term should be broadly interpreted as encompassing various types of projection system, including refractive optics, reflective optics, and catadioptric systems, for example. The radiation system may also include components operating according to any of these design types for directing, shaping or controlling the projection beam of radiation, and such components may also be referred to below, collectively or singularly, as a "lens". Further, the lithographic apparatus may be of a type having two or

more substrate tables (and/or two or more mask tables). In such "multiple stage" devices the additional tables may be used in parallel, or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposures. Dual stage lithographic apparatus are described, for example, in US 5,969,441 and US Serial No. 09/180,011, filed 27 February, 1998 (WO 98/40791), incorporated herein by reference.

Lithographic projection apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, the patterning means may generate a circuit pattern corresponding to an individual layer of the IC, and this pattern can be imaged onto a target portion (comprising one or more dies) on a substrate (silicon wafer) that has been coated with a layer of photosensitive material (resist). In general, a single wafer will contain a whole network of adjacent target portions that are successively irradiated via the projection system, one at a time. In current apparatus, employing patterning by a mask on a mask table, a distinction can be made between two different types of machine. In one type of lithographic projection apparatus, each target portion is irradiated by exposing the entire mask pattern onto the target portion in one go; such an apparatus is commonly referred to as a wafer stepper. In an alternative apparatus —commonly referred to as a step-and-scan apparatus — each target portion is irradiated by progressively scanning the mask pattern under the projection beam in a given reference direction (the "scanning" direction) while synchronously scanning the substrate table parallel or anti-parallel to this direction; since, in general, the projection system will have a magnification factor M (generally < 1), the speed V at which the substrate table is scanned will be a factor M times that at which the mask table is scanned. More information with regard to lithographic devices as here described can be gleaned, for example, from US 6,046,792, incorporated herein by reference.

Alignment is the process of positioning the image of a specific point on the mask to a specific point on the wafer which is to be exposed. Typically one or more alignment marks, such as a small pattern, are provided on each of the substrate and the mask. A device may consist of many layers which are built up by successive exposures with intermediate processing steps. Before each exposure, alignment between the markers on

the substrate and the mask is performed to minimize any positional error between the new exposure and the previous ones, which error is termed overlay error.

For some devices, e.g. micro-electro-mechanical systems (MEMS) and micro-opto-electro-mechanical systems (MOEMS), it is desirable to be able to create structures on both sides of a substrate using lithographic processes and in many cases, the structures on opposite sides of the substrate need to be aligned with each other. This means that it is necessary for the lithographic apparatus to align the pattern being projected onto the frontside of a substrate to alignment markers on the backside. This can be done with additional hardware, e.g. optics to project an image of a backside marker to the front side of the substrate or using a substrate that is transparent. Infra-red radiation can be used with a silicon substrate but has limited accuracy and may undesirably heat the wafer.

It is an object of the present invention to provide a device manufacturing method which can print structures on one side of a substrate aligned to markers on the other side without the need for additional hardware and with improved accuracy.

This and other objects are achieved according to the invention in a device manufacturing method comprising the steps of:

providing a first substrate having first and second surfaces;

patterning said first surface of said substrate with at least one reversed alignment marker;

providing a protective layer over said alignment marker(s);

bonding said first surface of said first substrate to a second substrate;

locally etching said first substrate as far as said protective layer to form a trench around the or each reversed alignment marker; and

forming at least one patterned layer on said second surface using a lithographic projection apparatus having a front-to-backside alignment system whilst aligning said substrate to the alignment markers revealed in the or each trench.

The reversed alignment marker formed in the first surface is revealed by the etch as a normally oriented alignment marker to which the lithographic projection apparatus can readily align. Patterns directly aligned to the marker printed on the frontside can therefore be printed on the backside of the substrate.

The protective layer which conforms to the shape of the marker is preferably formed of a material, e.g. SiO_2, selective against the etch used to form the trench(es) and hence forms an etch stop layer. A reflective layer, e.g. of Al, can be formed over the protective layer (before bonding) to increase the visibility of the marker when revealed in the trench.

The etch step can be localized by forming an etch-resistant layer, e.g. of oxide, on the second surface; providing a layer of radiation-sensitive resist on the etch-resistant layer; patterning and developing said resist so as to form openings above said marker(s); and removing said etch-resistant layer in said openings. To pattern the resist to form the openings, the markers only need to be located coarsely, which can be done to sufficient degree of accuracy using an infra-red mark sensor from the second side of the substrate.

Before the substrate is bonded to the second (carrier) substrate, devices may be formed in and/or on the first surface using known techniques. The protective layer and optional reflective layer may be formed as part of device layers, with any intervening layers locally removed as necessary, rather than being specially formed.

Normal alignment markers for use in aligning the structures in or on the first surface can be printed in the same step as the reverse alignment markers used to align the structures formed on the second surface. In this way, the positional relationship of the normal and reversed markers and hence of the structures on the first and second surfaces can be assured.

After bonding, the first substrate may be reduced in thickness, e.g. by grinding.

In a manufacturing process using a lithographic projection apparatus according to the invention a pattern (e.g. in a mask) is imaged onto a substrate that is at least partially covered by a layer of energy-sensitive material (resist). Prior to this imaging step, the substrate may undergo various procedures, such as priming, resist coating and a soft bake. After exposure, the substrate may be subjected to other procedures, such as a

post-exposure bake (PEB), development, a hard bake and measurement/inspection of the imaged features. This array of procedures is used as a basis to pattern an individual layer of a device, e.g. an IC. Such a patterned layer may then undergo various processes such as etching, ion-implantation (doping), metallization, oxidation, chemo-mechanical polishing, etc., all intended to finish off an individual layer. If several layers are required, then the whole procedure, or a variant thereof, will have to be repeated for each new layer. Eventually, an array of devices will be present on the substrate (wafer). These devices are then separated from one another by a technique such as dicing or sawing, whence the individual devices can be mounted on a carrier, connected to pins, etc. Further information regarding such processes can be obtained, for example, from the book "Microchip Fabrication: A Practical Guide to Semiconductor Processing", Third Edition, by Peter van Zant, McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4, incorporated herein by reference.

Although specific reference may be made in this text to the use of the apparatus according to the invention in the manufacture of ICs, it should be explicitly understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid-crystal display panels, thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "wafer" or "die" in this text should be considered as being replaced by the more general terms "substrate" and "target area", respectively.

In the present document, the terms illumination radiation and illumination beam are used to encompass all types of electromagnetic radiation, including ultraviolet radiation (e.g. with a wavelength of 365, 248, 193, 157 or 126 nm) and EUV, as well as particle beams, such as ion beams or electron beams.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which:

Figure 1 depicts a lithographic projection apparatus which can be used in the method of the invention;

Figure 2 is a plan view of a substrate showing the location of alignment markers used in eth method of the invention; and

Figures 3 to 8 illustrate steps in a method of manufacturing devices according to the invention.

In the Figures, corresponding reference symbols indicate corresponding parts.

Lithographic Projection Apparatus

Figure 1 schematically depicts a lithographic projection apparatus which can be used to perform steps of the method of the invention. The apparatus comprises:

- a radiation system LA, Ex, IL, for supplying a projection beam PB of radiation (*e.g.* UV radiation);
- a first object table (mask table) MT for holding a mask MA (*e.g.* a reticle), and connected to first positioning means for accurately positioning the mask with respect to item PL;
- a second object table (substrate table) WT for holding a substrate W (*e.g.* a resist-coated silicon wafer), and connected to second positioning means for accurately positioning the substrate with respect to item PL;
- a projection system ("lens") PL (*e.g.* a quartz lens system) for imaging an irradiated portion of the mask MA onto a target portion C (comprising one or more dies) of the substrate W.

As here depicted, the apparatus is of a transmissive type (*i.e.* has a transmissive mask). However, in general, it may also be of a reflective type, for example (with a reflective mask). Alternatively, the apparatus may employ another kind of patterning means, such as a programmable mirror array of a type as referred to above.

The radiation system comprises a source LA (*e.g.* a UV laser) that produces a beam of radiation. This beam is fed into an illumination system (illuminator) IL, either directly or after being passed through conditioning means, such as a beam expander Ex, for example. The illuminator IL comprises adjusting means AM for setting the outer

and/or inner radial extent (commonly referred to as σ-outer and σ-inner, respectively) of the intensity distribution in the beam. In addition, it will generally comprise various other components, such as an integrator IN and a condenser CO. In this way, the beam PB impinging on the mask MA has a desired uniformity and intensity distribution in its cross-section.

It should be noted with regard to Figure 1 that the source LA may be within the housing of the lithographic projection apparatus (as is often the case when the source LA is a mercury lamp, for example), but that it may also be remote from the lithographic projection apparatus, the radiation beam which it produces being led into the apparatus (e.g. with the aid of suitable directing mirrors); this latter scenario is often the case when the source LA is an excimer laser. The current invention and Claims encompass both of these scenarios.

The beam PB subsequently intercepts the mask MA which is held in a mask holder on a mask table MT. Having traversed the mask MA, the beam PB passes through the lens PL, which focuses the beam PB onto a target portion C of the substrate W. With the aid of the second positioning means (and interferometric measuring means IF), the substrate table WT can be moved accurately, *e.g.* so as to position different target portions C in the path of the beam PB. Similarly, the first positioning means can be used to accurately position the mask MA with respect to the path of the beam PB, *e.g.* after mechanical retrieval of the mask MA from a mask library, or during a scan. In general, movement of the object tables MT, WT will be realized with the aid of a long stroke module (coarse positioning) and a short stroke module (fine positioning), which are not explicitly depicted in Figure 1. However, in the case of a wafer stepper (as opposed to a step-and-scan apparatus) the mask table MT may just be connected to a short stroke actuator, or may be fixed.

The depicted apparatus can be used in two different modes:

1. In step mode, the mask table MT is kept essentially stationary, and an entire mask image is projected in one go (*i.e.* a single "flash") onto a target portion C.

The substrate table WT is then shifted in the x and/or y directions so that a different target portion C can be irradiated by the beam PB;

2. In scan mode, essentially the same scenario applies, except that a given target portion C is not exposed in a single "flash". Instead, the mask table MT is movable in a given direction (the so-called "scan direction", *e.g.* the x direction) with a speed v, so that the projection beam PB is caused to scan over a mask image; concurrently, the substrate table WT is simultaneously moved in the same or opposite direction at a speed $V = Mv$, in which M is the magnification of the lens PL (typically, $M = 1/4$ or $1/5$). In this manner, a relatively large target portion C can be exposed, without having to compromise on resolution.

Embodiment 1

Figure 2 shows a wafer W which is to be provided with devices on both sides and on which are provided normal markers (not shown) and reversed markers 1-8. The reversed markers 1-8 are mirror images - about the axis about which the wafer is to be rotated, in this case the Y axis - of the normal markers. The normal markers may take any convenient form, such as a grating, a group of gratings, box-in-box, frame-in-frame, chevrons, etc., as known in the art, and may form the primary markers used for global alignment of the substrate prior to a series of exposures. In Figure 2, examples of a reverse primary marker and, for reference, a normal primary marker, each formed by four gratings, are shown. Of the four gratings, a pair are horizontal and a pair vertical and, though not apparent from the drawing, the two gratings of each pair have different periods in a known manner. In the present example the markers are provided at symmetrical positions on the wafer axes. The present invention may of course also be applied to other markers, e.g. markers adjacent each target area or die.

Figures 3 to 8 illustrate steps in an example of the method of the invention. Firstly, normal markers (not shown) and reversed markers 1-8 are etched into first surface 10a of wafer W in a known manner and covered by a protective layer 11 of SiO_2 and a

reflective layer 12 of Al, as shown in Figure 3, which is a partial cross-section along the Y axis of Figure 2. The substrate W is then flipped over and bonded to carrier substrate CW with a layer of adhesive 13. Figure 4 shows the substrate W bonded to the carrier substrate CW, with the second surface 10b uppermost.

As shown in Figure 5, the wafer W is ground to a desired thickness, T, e.g. of about 70μm, and the upper surface 10b' finished as required for the devices to be formed on it.

To locally etch through the first substrate to reveal the reversed markers 1-8, the second surface 10b' is first covered with a layer of oxide 14, e.g. by deposition, as shown in Figure 6 and a layer of resist 15 which is exposed to open primary flood windows 16 above the reversed markers 1-8. Since the primary flood windows 16 are rather larger than the markers they do not have to be accurately located and the exposure step to form them can be carried out after the markers have been located using a coarse alignment tool, such as a mark sensor using infra-red, that can detect the reversed markers through the substrate W.

The oxide layer 14 is removed in the windows 16 by a dry etch RIE or wet etch (Buffered Oxide Etch Containing HF) step to form a hardmask and a deep trench etch using an etchant selective to Si is performed to form trenches 17. The deep trench etch ends on the SiO_2 layer and so the trenches 17 extend down to the reversed primary markers 1, 5 to reach the position shown in Figure 8. Thereafter, device layers can be formed on the second surface 10b' with alignment to the reversed markers 1-8 revealed in trenches 17. The trenches have a width d_1 at their tops that is sufficient, e.g. 1200μm, to ensure that the width d_2 at their base is large enough, e.g. 1000μm, to accommodate comfortably the markers 1-8. The oxide layer 14 is then removed prior to continued processing.

The first step in continued processing of the bonded substrate may be to print further markers, at known positions relative to the revealed markers, on the second surface 10b', now uppermost, of the wafer. The further markers can be aligned to in the further processing of the second surface more conveniently than the revealed markers.

Whilst specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. The description is not intended to limit the invention.

CLAIMS:

1. A device manufacturing method comprising the steps of:

providing a first substrate having first and second surfaces;

patterning said first surface of said substrate with at least one reversed alignment marker;

providing a protective layer over said alignment marker(s);

bonding said first surface of said first substrate to a second substrate;

locally etching said first substrate as far as said protective layer to form a trench around the or each reversed alignment marker; and

forming at least one patterned layer on said second surface using a lithographic projection apparatus having a front-to-backside alignment system whilst aligning said substrate to the alignment marker(s) revealed in the or each trench.

2. A method according to claim 1 wherein said protective layer is formed of a material, e.g. SiO_2, selective against the etch used to form the trench(es) and hence forms an etch stop layer.

3. A method according to claim 1 or 2 comprising the further step of forming a reflective layer, e.g. of Al, over the protective layer prior to said step of bonding to increase the visibility of the marker when revealed in the trench.

4. A method according to claim 1, 2 or 3 comprising the further step, before said step of bonding, of forming devices in and/or on the first surface.

5. A method according to claim 4 wherein said protective layer, and/or said reflective layer if provided, are formed as part of device layers, with any intervening layers locally removed as necessary

6. A method according to claim 4 or 5 wherein normal alignment markers for use in aligning the structures in or on the first surface are printed in the same step as said reverse alignment markers.

7. A method according to any one of the preceding claims wherein said step of locally etching comprises the substeps of forming an etch-resistant layer, e.g. of oxide, on the second surface; providing a layer of radiation-sensitive resist on the etch-resistant layer; patterning and developing said resist so as to form openings above said marker(s); and removing said etch-resistant layer in said openings.

8. A method according to any one of the preceding claims comprising the further step, after said step of bonding, of reducing the thickness of said first substrate, e.g. by grinding.

9. A method according to any one of the preceding claims wherein said alignment marker(s) is(are) patterned using the same apparatus as is used for patterning the process layers.

10. A method according to any one of the preceding claims wherein said step of forming at least one patterned layer on said second surface includes the formation of at least one further alignment marker at a known position relative to the alignment marker(s) revealed in the or each trench.

ABSTRACT

Device Manufacturing Method

A device manufacturing method comprising the steps of:

providing a first substrate having first and second surfaces;

patterning said first surface of said substrate with at least one reversed alignment marker;

providing a protective layer over said alignment marker(s);

bonding said first surface of said first substrate to a second substrate;

locally etching said first substrate as far as said protective layer to form a trench around the or each reversed alignment marker; and

forming at least one patterned layer on said second surface using a lithographic projection apparatus having a front-to-backside alignment system whilst aligning said substrate to the alignment markers revealed in the or each trench.

Fig. 8

Fig. 1

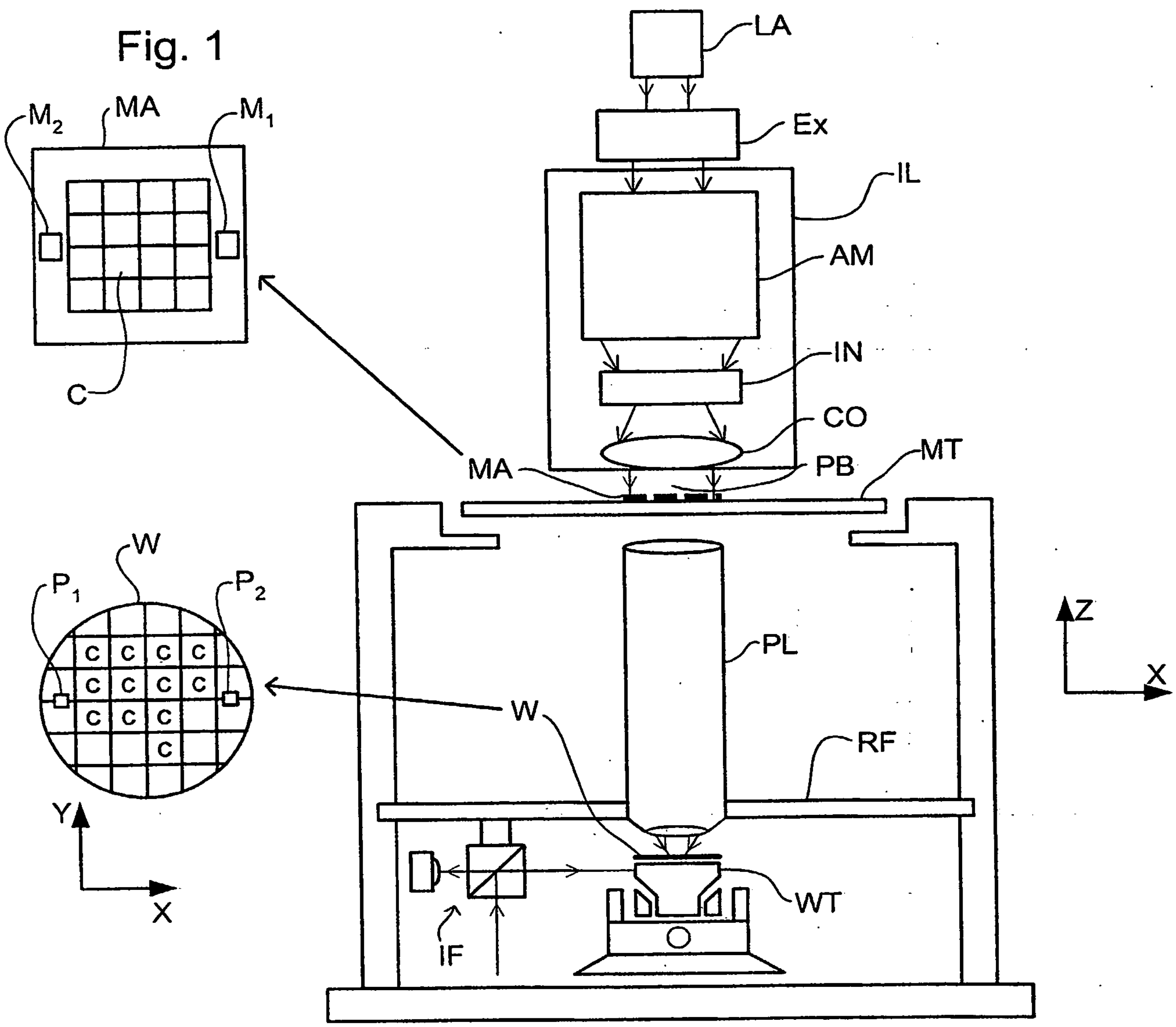

Fig. 2

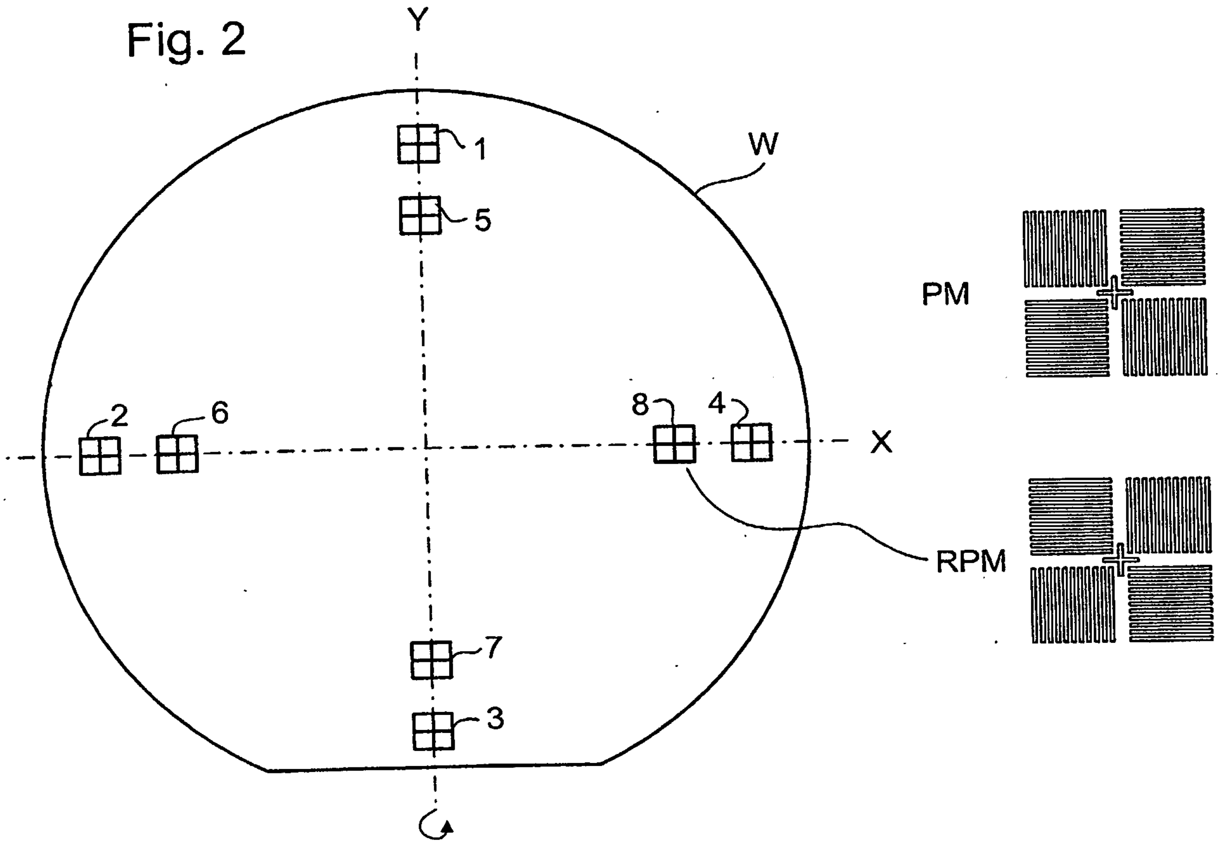

Fig. 3

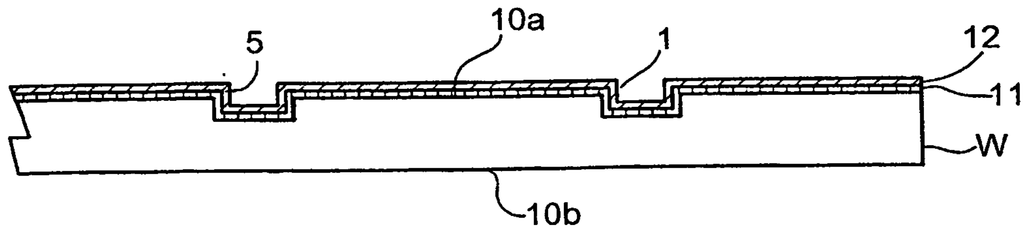

Fig. 4

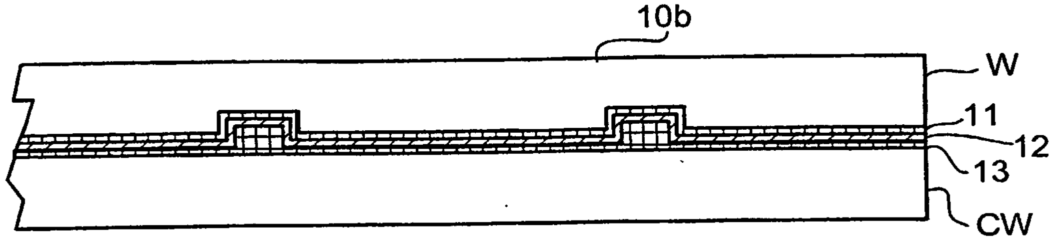

Fig. 5

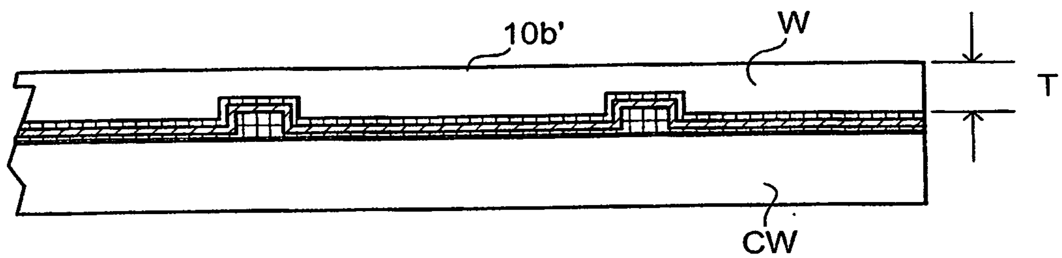

Fig. 6

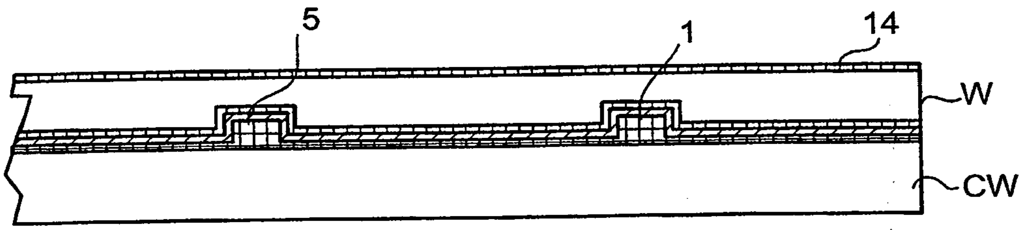

Fig. 7

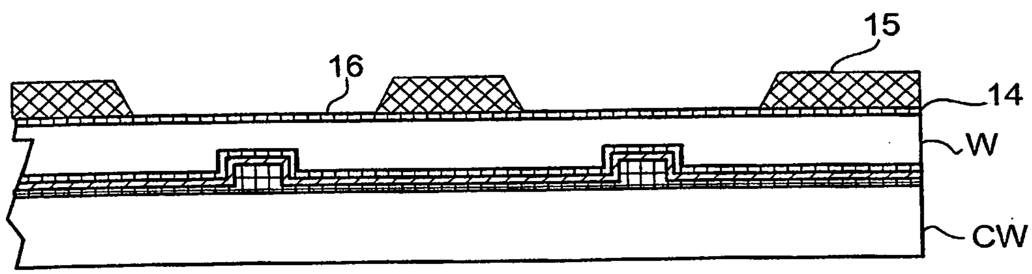

Fig. 8